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AN INVESTIGATION OF LANDING-CONTACT CONDITIONS FOR SEVERAL TURBOJET TRANSPORTS DURING ROUTINE DAYLIGHT OPERATIONS AT NEW YORK INTERNATIONAL AIRPORT

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SUMMARY

An investigation was conducted to determine the landing-contact parameters for five types of turbojet transports (designated herein as turbojets A, B, C, D, and E) landing on runway 22L at New York International Airport. Measurements were taken photographically during routine daylight operations to obtain vertical velocity, airspeed, rolling velocity, and bank angle. Although all the landing parameters were evaluated for all the transports, the analysis for three types of turbojets (A, D, and E) was limited to the mean vertical velocity and airspeed for which the sample size was considered to be adequate.

The results indicated that the mean vertical velocities for all the turbojet transports of this investigation ranged from 1.7 ft/sec to 1.9 ft/sec. These mean values were approximately 0.3 ft/sec higher than those measured for two similar types of transports of previous investigations conducted at the Los Angeles International Airport. For two types of turbojets (B and C), 1 landing in 100 would be expected to exceed a vertical velocity at touchdown of approximately 4.0 ft/sec. Mean values of airspeed at touchdown for the five types of transports ranged from 117 knots to 128 knots. The probability distribution of airspeeds for turbojet B agreed well with that for the same type in the previous investigation at Los Angeles when 1 landing in 100 was expected to equal or exceed approximately 137 knots. For the same probability, another type of turbojet (C) is expected to equal or exceed an airspeed at landing of about 148 knots. Mean rolling velocities rolling toward and away from the first wheel to touch for turbojet B were 1.7°/sec and 1.0°/sec, respectively, and for turbojet C were 1.2°/sec and 0.9°/sec, respectively. Mean values of bank angle for these two types of turbojets were 0.6° and 0.4°, respectively.

INTRODUCTION

Landing-contact conditions of several turbine-powered transports were determined in investigations conducted at the Los Angeles International Airport and are reported in references 1 and 2. Results indicated that the turbojet transports of references 1 and 2 experienced significantly higher vertical velocities at touchdown than either the piston-engine transports (refs. 3 and 4) or the turboprop transport (ref. 1). At the time of the investigations of references 1 and 2, relatively few of the larger intercontinental turbojet transports were in operation and, hence, no information on their landing-contact conditions was obtained. Since that time more of these larger transports have entered into commercial service and at the time of the present investigation were landing in large enough numbers for an adequate sample size to be obtained in a reasonable period of time. The present investigation was, therefore, undertaken at the New York International Airport to obtain the landing-contact conditions of these larger transports. At the same time, measurements were also made of the landing-contact parameters of four other types of turbojet transports.

This report presents results for a total of 331 landings, and the number of landings were distributed as follows: 42 for turbojet A, 108 for turbojet B, 107 for turbojet C, 40 for turbojet D, and 34 for turbojet E. The landing-contact conditions measured included vertical velocity, airspeed, bank angle, rolling velocity, and distance of point of touchdown from the runway threshold. The touchdown distance from the runway threshold was not analyzed because terrain interference prohibited the recording of landings beyond a distance of approximately 1,800 feet from the threshold. However, since a review of the data from references 1 and 2 indicated no correlation between touchdown distance and any of the other measured parameters, this loss of landings is believed not to have affected the remaining results. A summary containing many of these attempted correlations of landing-contact conditions for both piston-engine and turbine-powered transports is presented in reference 5. In view of the small sample size for three types of turbojets, the analysis of the results for these transports was limited to the mean values of vertical velocity and airspeed for which the sample size was considered adequate.

APPARATUS AND METHOD

Landing data were obtained photographically by the method described in reference 6. The equipment was set up at New York International Airport approximately 875 feet from runway 22L at a spot from which a clear

view could be obtained of the most probable touchdown area of the transports. Because of terrain interference it was possible to photograph only the first 1,800 feet of the 8,400-foot runway. A diagram indicating the location of the camera and the approximate area blocked by the terrain is shown in figure 1.

Photographs were obtained for a total of 331 landings of the five types of turbojet transports during routine daylight operation and under nongusty-wind conditions. The data were reduced according to the method in references 4 and 6 to obtain values of vertical velocity, airspeed, rolling velocity, and bank angle. Airspeed values presented in this report are true airspeed as determined from the airplane ground speed and the wind velocity measured at the camera site prior to each landing.

The general characteristics of the aircraft investigated are listed in table I. The identification of turbojets A and B remains consistent with that of references 1 and 2.

RESULTS AND DISCUSSION

The results of this investigation are presented in table II for all five types of aircraft. Distributions indicating the probability of a measured parameter equalling or exceeding a given value are presented in figures 2 to 7. The distributions of vertical velocity and airspeed were faired by means of a Pearson Type III method. (See ref. 7.) This method permits extrapolation to be made on a mathematical, rather than a visual, basis.

The terrain interference caused a loss of the number of landings measured; therefore, no attempt was made to analyze or discuss the parameter of touchdown distance from the runway threshold. In view of the relatively small sample size for turbojets A, D, and E in this investigation, discussion of the results is primarily limited to turbojets B and C and these results are compared with previous results for turbojets A and B of references 1 and 2.

Vertical Velocity

Probability distributions of vertical velocity at touchdown for turbojets B and C are presented in figure 2. The two distributions are similar and indicate, for example, that for each type of turbojet 1 landing in 100 would be expected to equal or exceed a vertical velocity of approximately 4.0 ft/sec. The mean values of vertical velocity determined for turbojets B and C were 1.8 ft/sec and 1.9 ft/sec, respectively.

In figure 3 a comparison is made of the overall distributions of the vertical velocity for turbojets B and C landing at New York International Airport and turbojets A and B (refs. 1 and 2) landing at Los Angeles International Airport. This comparison shows that the shape of the distributions is somewhat different and that the mean values measured at New York are approximately 0.3 ft/sec higher than those measured at Los Angeles. The reasons for the differences in shape of these distributions are not known.

In view of the small data samples for turbojets A, D, and E, no attempt was made to extrapolate the data using the Pearson Type III fairing. However, the unfaired cumulative frequency points are plotted in figure 4, and they are compared with the range of cumulative frequency points (in which 100 or more landings of each type were included) obtained for turbojets B and C in this investigation and for turbojets A and B of references 1 and 2. This comparison indicates that the smaller data samples of turbojets A, D, and E are in reasonable agreement with the larger data samples and are of sufficient number to predict a fairly reliable mean vertical velocity. The mean vertical velocity determined for turbojets A and E was 1.8 ft/sec and for turbojet D was 1.7 ft/sec.

Airspeed

Probability distributions of airspeed in knots at touchdown as shown in figure 5 indicate that turbojet B in this investigation has a similar distribution to that of turbojet B in reference 1. The mean values of touchdown airspeed for turbojets B and C were 117 knots and 128 knots, respectively, with 1 landing in 100 expected to exceed approximately 137 knots for turbojet B and 148 knots for turbojet C. The mean values of airspeed at touchdown for turbojets A, D, and E were 128 knots, 125 knots, and 127 knots, respectively.

Rolling Velocity

Rolling velocities are presented in figure 6 as either rolling toward or away from the first wheel to touch. For turbojet B (fig. 6(a)) and turbojet C (fig. 6(b)) the approximate percentage of landings made rolling toward the first wheel to touch were 57 and 58 percent, respectively. Mean rolling velocities for turbojet B were 1.7°/sec (toward) and 1.0°/sec (away) and for turbojet C were 1.2°/sec (toward) and 0.9°/sec (away).

Bank Angle

Cumulative-frequency distributions of bank angle at touchdown for turbojets B and C are presented in figure 7. The mean values for turbojets B and C were 0.6° and 0.4°, respectively.

CONCLUSIONS

An investigation has been made to determine the landing-contact parameters of vertical velocity, airspeed, rolling velocity, and bank angle for five types of turbojet transports (designated turbojets A, B, C, D, and E) landing during daylight hours on runway 22L at New York International Airport. Although all the landings were evaluated for all the transports, the analysis for three types of turbojets (A, D, and E) was limited to the mean values of vertical velocity and airspeeds for which the sample size was considered adequate. Results of this investigation have led to the following conclusions:

1. The probability distributions of vertical velocity at touchdown for two types of turbojets (designated turbojets B and C) were similar and indicated that 1 landing in 100 might be expected to equal or exceed a vertical velocity of approximately 4.0 ft/sec. The mean vertical velocities for all five types of transports ranged from 1.7 ft/sec to 1.9 ft/sec. These mean velocities are approximately 0.3 ft/sec higher than those measured for two similar types of turbojets in previous investigations conducted at the Los Angeles International Airport.

2. Distributions of airspeed in knots at touchdown indicate that turbojet B agrees well with the distribution obtained previously for the same turbojet at the Los Angeles International Airport. Mean values of airspeed for turbojets B and C were 117 knots and 128 knots, respectively, and 1 landing in 100 was expected to exceed approximately 137 knots for turbojet B and 148 knots for turbojet C. The mean values of airspeed at touchdown for turbojets A, D, and E were 128 knots, 125 knots, and 127 knots, respectively.

3. Mean rolling velocities rolling toward and away from the first wheel to touch for turbojet B were 1.7°/sec and 1.0°/sec, respectively, and for turbojet C were 1.2°/sec and 0.9°/sec, respectively.

4. Mean values of bank angle for turbojets B and C were 0.6° and 0.4°, respectively.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., July 13, 1962.

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TABLE I.- GENERAL CHARACTERISTICS FOR THE FIVE TEST AIRPLANES

Turbojet transport A:	
Maximum gross take-off weight, lb	245,000
Maximum permissible landing weight, lb	175,000
Empty weight, lb	113,640
Wing area, sq ft	2,433
Wing span, ft	130.8
Stall speed (175,000 lb), knots	105.6
Sweepback (25-percent-chord line), deg	35
Turbojet transport B:	
Maximum gross take-off weight, lb	265,000
Maximum permissible landing weight, lb	190,500
Empty weight, lb	120,200
Wing area, sq ft	2,770.6
Wing span, ft	142.4
Stall speed (200,000 lb), knots	105.0
Sweepback (25-percent-chord line), deg	30.0
Turbojet transport C:	
Maximum gross take-off weight, lb	316,000
Maximum permissible landing weight, lb	207,000
Empty weight, lb	132,924
Wing area, sq ft	2,892
Wing span, ft	142.5
Stall speed (186,000 lb), knots	102
Sweepback (25-percent-chord line), deg	35
Turbojet transport D:	
Maximum gross take-off weight, lb	230,000
Maximum permissible landing weight, lb	175,000
Empty weight, lb	104,763
Wing area, sq ft	2,433
Wing span, ft	130.8
Stall speed (130,000 lb), knots	97
Sweepback (25-percent-chord line), deg	35
Turbojet transport E:	
Maximum gross take-off weight, lb	184,500
Maximum permissible landing weight, lb	132,800
Empty weight, lb	81,800
Wing area, sq ft	2,000
Wing span, ft	120.0
Stall speed (130,000 lb), knots	117.0
Sweepback (30-percent-chord line), deg	35

TABLE II.- RESULTS OF MEASURED LANDING-CONTACT PARAMETERS FOR 331 LANDINGS OF FIVE TYPES OF TURBOJET TRANSPORTS

(a) Turbojet A (42 landings)

Landing identification number	Vertical velocity, ft/sec	Horizontal velocity, knots	Rolling velocity, deg/sec	Bank angle, deg	Airspeed, knots	Touchdown distance, ft
116	2.7	143.5	0.4	0.34	143.5	1,353
121	2.9	113.7	1.1	1.56	120.2	868
148	3.2	119.8	2.7	.59	126.7	1,292
149	2.0	117.7	0	.25	125.0	1,170
150	1.3	121.4	.4	.05	128.3	1,417
201	1.8	130.1	3.4	3.80	144.8	808
213	1.1	124.2	.3	.44	134.1	922
246	1.9	124.6	0	.32	132.3	1,602
275	2.9	121.8	.6	.59	126.9	234
287	1.7	112.4	.5	.72	117.5	1,273
289	1.2	126.4	.4	.04	131.5	1,557
313	1.0	116.4	.4	.08	128.2	1,432
315	1.2	113.7	.8	.27	126.5	1,147
320	1.6	120.7	.4	.07	133.5	1,191
325	1.9	110.0	.3	.45	122.2	371
334	2.1	111.3	.4	.53	121.1	1,329
336	1.9	110.5	0	.89	120.3	1,017
350	1.8	118.8	.8	.16	135.5	1,257
364	2.2	107.2	2.7	.61	122.9	364
387	.9	102.7	.4	.34	119.1	1,451
388	1.4	116.0	0	.14	132.4	957
402	1.9	108.2	.4	.26	118.0	1,419
403	1.3	112.3	.4	.11	122.7	911
412	2.3	107.2	0	.20	116.6	349
436	1.2	114.3	.4	.35	122.2	1,363
444	2.3	99.8	.4	.74	107.8	1,195
460	4.7	116.6	0	.09	125.4	1,724
481	1.8	126.5	1.2	.04	134.0	1,444
490	2.2	111.4	.3	.17	118.9	1,216
501	1.7	129.3	.4	.06	134.9	423
503	1.6	126.5	3.2	.99	132.1	1,086
518	1.2	138.0	0	.11	142.4	1,593
521	1.1	131.6	0	.39	134.1	919
537	.1	126.7	0	.11	130.5	1,118
546	2.5	125.0	.4	.32	131.5	1,475
547	2.4	133.1	.4	.05	139.7	1,257
557	2.2	116.1	4.6	.02	121.7	1,658
563	2.5	128.7	2.1	.18	131.5	998
569	1.9	132.5	2.2	.20	135.3	1,241
579	1.0	116.5	4.5	.35	119.5	423
580	.9	125.5	1.8	.24	130.2	1,616
587	.7	131.9	2.0	.40	138.9	1,463

TABLE II.- RESULTS OF MEASURED LANDING-CONTACT PARAMETERS FOR 331 LANDINGS OF FIVE TYPES OF TURBOJET TRANSPORTS - Continued

(b) Turbojet B (108 landings)

Landing identification number	Vertical velocity, ft/sec	Horizontal velocity, knots	Rolling velocity, deg/sec	Bank angle, deg	Airspeed, knots	Touchdown distance, ft
115	2.2	117.1	1.9	0.23	119.1	1,098
119	.7	117.2	0	.35	122.2	1,135
122	2.1	115.2	0	.19	121.7	1,201
126	1.6	117.8	.4	.39	124.4	1,044
132	3.8	105.0	1.5	.09	114.4	1,611
151	1.4	109.4	0	.06	115.7	1,329
158	1.1	117.6	.5	.13	121.4	1,511
170	2.8	118.2	0	.03	120.5	789
174	2.3	112.3	.5	2.15	116.6	1,070
181	3.3	136.4	3.0	.24	142.5	811
184	2.5	116.3	0	.45	119.8	1,156
185	1.0	131.4	1.9	.46	134.8	1,072
188	3.0	111.8	2.3	.95	112.6	739
189	.7	115.5	3.0	1.47	124.0	708
195	1.3	110.7	4.2	.09	121.4	1,039
207	1.9	118.1	.5	.04	131.1	1,536
215	3.8	108.9	3.0	1.16	118.8	730
248	1.0	117.3	.4	2.25	125.0	783
252	1.9	117.4	.8	.35	125.9	1,336
253	2.5	122.2	1.1	.83	130.7	644
254	1.8	112.1	.7	.95	120.6	1,168
256	.3	111.2	1.5	.13	116.9	764
267	3.1	129.7	5.6	.49	135.8	107
271	.4	113.1	.5	.20	118.3	305
283	2.3	109.5	.1	.53	113.9	268
284	1.6	105.9	.5	.80	110.3	1,182
286	.6	104.5	.4	.89	109.7	905
293	1.7	108.6	2.2	.40	113.8	1,028
296	2.1	113.0	.4	.03	117.4	1,349
297	.5	110.8	.4	.47	115.1	943
298	.1	104.2	.1	.31	108.5	1,619
301	2.9	112.5	1.2	.20	118.5	1,257
303	3.9	117.7	.5	.37	117.7	1,346
306	1.9	116.8	0	.30	121.7	697
307	1.7	110.5	1.2	.04	118.4	1,204
308	2.3	105.1	.7	.67	113.0	1,219
314	2.8	101.0	.4	1.06	113.8	903
318	1.9	101.3	.1	.17	114.1	1,479
328	2.3	106.7	.4	.09	117.5	1,353
329	1.3	112.8	.6	.58	122.6	305
338	3.4	100.0	.1	.86	109.9	1,292
340	1.5	110.9	.4	1.92	122.7	965
343	.3	105.9	.4	.01	118.7	1,056
345	1.9	93.0	1.2	.49	110.7	1,025
347	1.5	104.1	4.5	.53	120.3	941
349	1.5	89.2	6.5	.29	106.0	1,495
352	1.5	95.8	6.7	.23	111.5	1,036
354	1.1	101.3	.4	.70	117.0	911
371	1.8	113.6	.7	.24	130.3	919
372	2.6	111.8	.4	.60	128.6	1,222
374	2.6	106.1	.4	.62	122.8	992
376	1.0	90.2	1.2	.28	106.9	1,112
380	3.0	97.4	1.0	.53	114.2	1,414
383	2.3	95.9	.3	.70	111.6	1,353
397	3.2	97.5	3.0	.58	113.3	965
399	3.0	114.6	0	.08	125.4	102

TABLE II.- RESULTS OF MEASURED LANDING-CONTACT PARAMETERS FOR 331 LANDINGS OF FIVE TYPES OF TURBOJET TRANSPORTS - Continued

(b) Turbojet B (108 landings) - Concluded

Landing identification number	Vertical velocity, ft/sec	Horizontal velocity, knots	Rolling velocity, deg/sec	Bank angle, deg	Airspeed, knots	Touchdown distance, ft
400	2.8	98.8	1.2	2.03	109.6	1,056
408	2.0	93.6	0	.05	103.9	1,191
409	1.7	95.7	1.4	4.04	105.1	1,144
416	1.3	94.5	4.6	.18	104.9	1,332
419	1.2	98.0	.5	.69	109.2	1,269
421	1.4	112.0	.4	.44	127.0	170
424	2.1	96.4	.1	.55	111.5	1,308
426	1.5	101.4	.8	.22	115.5	1,432
427	2.2	100.2	4.6	1.98	114.3	1,050
432	1.0	98.0	.1	.68	113.0	1,639
437	2.6	107.5	.4	.53	115.4	981
439	.6	137.0	.4	.50	144.0	1,483
445	1.6	105.8	1.7	.74	112.8	1,511
446	.9	106.7	2.8	.19	114.7	1,279
453	1.1	102.0	3.4	.48	111.0	1,186
462	1.6	105.8	2.0	2.15	114.7	1,118
465	.1	106.2	.5	.11	114.7	1,579
467	1.8	103.8	1.2	1.57	112.2	1,042
471	.6	97.8	2.7	.35	107.2	1,182
474	2.1	108.0	0	.67	117.4	1,061
479	2.0	103.4	.4	.35	112.8	1,463
480	.9	96.7	1.3	.01	106.1	1,444
485	.5	106.0	.4	.47	114.5	1,536
489	1.6	105.7	.7	.63	113.4	1,238
494	.7	109.7	.4	.06	117.2	1,459
496	1.0	97.4	.1	.75	103.9	1,611
497	2.9	99.5	1.9	.20	106.1	1,127
498	.9	107.3	.8	.37	113.9	1,011
507	.8	101.1	3.0	.18	106.8	905
509	.3	110.6	.4	.66	116.2	412
515	3.3	107.6	1.2	.31	111.0	1,385
520	1.8	107.5	.4	.47	110.9	1,250
526	3.1	118.4	.4	.14	121.0	1,308
528	1.6	114.9	1.6	.14	117.5	1,295
531	2.7	109.6	.5	.95	114.2	1,250
532	1.4	113.2	.3	.42	117.7	1,207
541	2.1	107.2	1.1	.47	113.6	919
542	.9	116.3	5.3	.03	122.7	1,072
543	2.2	111.6	.4	.59	117.9	1,584
544	1.5	-----	.4	.40	-----	1,295
545	1.9	111.0	.9	.41	117.6	1,597
548	2.2	112.1	.4	.06	118.7	979
550	2.4	107.3	.7	.84	113.9	1,269
556	2.2	111.8	.1	.48	117.4	1,455
561	1.3	115.1	2.1	.47	118.9	1,440
562	2.8	108.2	1.2	.84	111.0	1,377
572	1.6	118.0	.9	.77	120.8	1,374
583	1.4	110.3	5.1	.27	115.0	1,195
584	1.3	117.1	.1	1.56	121.8	1,070
586	.9	113.7	2.2	.42	119.7	911
589	2.1	111.8	1.2	1.99	120.8	1,064
591	2.3	109.9	1.5	.57	118.9	1,056

TABLE II.- RESULTS OF MEASURED LANDING-CONTACT PARAMETERS FOR 331 LANDINGS OF FIVE TYPES OF TURBOJET TRANSPORTS - Continued

(c) Turbojet C (107 landings)

Landing identification number	Vertical velocity, ft/sec	Horizontal velocity, knots	Rolling velocity, deg/sec	Bank angle, deg	Airspeed, knots	Touchdown distance, ft
128	2.4	124.5	0.7	0.19	133.0	965
135	.7	130.4	.4	.12	138.8	1,101
137	2.6	106.5	0	.43	115.0	786
139	1.5	125.1	1.4	.37	132.6	938
153	2.6	126.1	1.3	.03	131.8	1,499
155	2.4	151.4	1.1	.34	154.7	943
157	2.7	130.3	0	.34	135.6	1,339
175	1.6	118.6	.5	.32	122.9	1,606
178	.7	127.9	.3	.33	132.2	1,132
180	.7	131.6	.5	.22	137.7	1,849
186	1.9	118.1	.3	.55	120.7	1,118
198	.6	123.9	.7	.11	137.0	1,207
199	2.8	124.0	.3	.06	137.2	714
200	.9	125.6	.4	.11	139.1	485
202	2.4	125.4	3.2	.28	136.1	822
244	2.7	124.5	.7	.02	132.1	1,241
261	1.7	126.0	.7	.13	131.6	1,106
280	1.0	121.7	2.1	.27	126.0	1,078
282	3.3	125.9	.8	.29	130.2	301
285	1.6	107.5	.8	.39	112.7	1,228
290	2.2	114.1	.7	1.42	119.3	968
291	1.2	120.4	.7	1.03	125.6	1,050
292	2.7	112.4	.4	.28	117.6	1,276
294	1.9	119.8	.1	.38	125.9	1,332
299	1.9	125.6	1.3	.66	128.2	478
304	1.6	132.3	.4	.28	132.3	1,308
305	2.8	126.0	1.0	.02	130.9	1,756
310	1.8	116.2	.7	.13	125.1	1,234
316	1.5	115.7	0	.55	128.5	935
317	3.0	118.7	1.1	.10	131.5	1,058
324	1.8	120.9	.8	.11	133.1	1,336
326	1.7	101.2	1.5	.75	112.0	1,020
339	.9	124.5	.8	.14	136.3	1,182
342	2.1	105.0	.1	.39	116.8	1,336
346	.9	121.1	.1	.62	137.8	97
348	1.9	103.0	0	.24	119.8	927
355	1.1	131.5	2.0	2.63	147.3	1,050
356	3.3	108.5	.3	.17	124.2	911
357	1.8	104.0	1.1	.17	119.8	908
360	2.4	121.0	1.2	.35	136.0	656
363	2.1	112.8	.8	.01	128.6	1,336
365	1.2	108.7	1.9	.19	124.5	951
373	1.4	98.6	.3	.11	115.3	747
375	4.0	112.0	.6	.41	128.7	175
379	3.2	106.1	.1	.31	122.9	207
386	1.2	106.3	1.4	1.49	122.7	1,129
401	1.5	112.3	6.2	.26	123.2	1,168
405	2.1	111.8	0	.10	122.2	802
407	1.7	112.0	.4	.94	123.0	1,064
411	2.1	109.9	1.1	.19	119.3	1,222
413	1.5	98.6	.4	.06	109.9	1,495
414	2.5	124.9	.4	.09	136.2	1,312
420	.1	107.2	.9	.28	119.4	1,440
425	1.2	96.8	.3	.66	110.9	938

TABLE II.- RESULTS OF MEASURED LANDING-CONTACT PARAMETERS FOR 331 LANDINGS OF FIVE TYPES OF TURBOJET TRANSPORTS - Continued

(c) Turbojet C (107 landings) - Concluded

Landing identification number	Vertical velocity, ft/sec	Horizontal velocity, knots	Rolling velocity, deg/sec	Bank angle, deg	Airspeed, knots	Touchdown distance, ft
428	1.3	102.7	0.8	0.04	116.8	699
431	1.7	101.6	.5	.51	116.6	1,325
433	2.8	110.7	1.7	.45	125.7	949
434	1.2	96.6	1.4	.37	110.7	1,257
441	3.3	127.8	1.3	.11	135.8	1,540
447	2.9	118.8	1.1	.81	126.8	1,047
450	2.1	126.7	1.0	.91	132.7	1,067
454	2.7	114.6	.4	.32	123.6	1,312
458	3.2	105.5	.4	.21	114.3	1,129
472	2.0	116.9	3.2	.17	126.3	995
473	1.3	113.0	1.1	.08	122.4	1,165
476	1.4	120.2	.4	.31	129.6	1,053
482	3.3	117.2	1.5	.24	124.7	1,273
493	1.7	121.8	0	.06	129.3	1,011
510	1.2	105.6	4.6	.15	109.4	1,056
511	2.4	120.0	0	.26	123.8	887
513	2.0	118.0	0	.81	122.6	1,112
514	2.5	117.4	.3	.40	122.0	1,231
533	1.2	121.8	2.2	.33	125.6	1,086
540	1.6	128.5	.4	.28	133.9	745
549	2.0	126.0	0	.17	132.6	1,392
553	3.5	128.5	3.5	.40	134.1	337
554	.9	113.6	1.0	.39	119.3	1,588
555	2.6	118.9	.7	.20	124.5	1,250
558	1.6	127.6	0	.10	133.2	1,593
560	2.0	122.3	0	.01	127.9	1,417
567	3.1	125.6	0	.07	128.4	960
571	2.0	118.4	.1	.53	121.2	1,444
573	.9	120.8	1.7	.13	123.6	1,532
582	2.8	112.4	0	.11	117.1	930
588	1.1	118.0	.3	.37	127.0	1,072
594	1.8	118.6	.5	.33	128.6	1,471
597	1.8	139.8	.3	.16	149.8	919
598	2.7	109.1	.1	.42	123.2	1,234
600	.5	118.9	2.8	.39	135.8	1,022
601	3.0	131.8	.4	.05	153.4	1,115
602	1.1	132.2	1.8	.72	140.5	881
604	1.8	118.0	.4	1.43	125.6	992
606	1.4	135.1	1.0	.37	142.7	1,099
607	1.9	123.2	.1	.67	130.9	1,471
608	1.1	132.6	.4	.12	138.7	1,579
609	1.7	120.8	.6	.78	125.2	1,644
611	1.5	120.4	.7	1.32	125.6	1,067
612	2.8	119.7	.4	.26	124.9	1,487
613	1.0	119.3	0	.25	124.5	1,109
615	2.0	123.6	.8	.48	128.6	1,269
618	2.0	125.6	1.5	.18	129.4	1,127
619	.4	128.0	.4	.44	131.8	800
621	1.2	140.9	.4	.04	146.2	1,653
622	3.1	-----	.3	.15	-----	1,213
623	1.2	137.1	2.3	.44	142.4	1,292
624	2.0	125.1	.7	.16	131.2	900
625	1.4	120.9	4.3	.17	127.0	1,346

TABLE II.- RESULTS OF MEASURED LANDING-CONTACT PARAMETERS FOR 331 LANDINGS OF FIVE TYPES OF TURBOJET TRANSPORTS - Continued

(d) Turbojet D (40 landings)

Landing identification number	Vertical velocity, ft/sec	Horizontal velocity, knots	Rolling velocity, deg/sec	Bank angle, deg	Airspeed, knots	Touchdown distance, ft
118	2.1	123.4	0.4	0.01	127.4	1,017
123	1.2	114.0	.4	1.28	120.6	1,006
138	.6	121.5	.4	.12	129.0	1,153
141	1.8	129.9	.4	.06	139.3	1,329
169	1.6	115.8	0	.18	118.1	1,210
183	1.3	127.3	0	.46	130.7	1,263
191	3.4	116.4	3.2	.45	129.4	960
192	2.6	115.2	1.6	.41	128.3	1,425
241	2.9	132.5	0	.06	142.8	1,302
243	1.0	123.4	.4	.03	131.1	1,432
251	1.1	119.2	.4	.01	127.6	1,285
266	.3	121.6	1.2	.14	126.2	537
277	.9	126.2	.7	.13	131.4	1,115
300	1.8	109.9	.1	.36	115.9	1,544
327	3.6	118.0	3.6	.14	128.8	44
331	.5	110.2	.8	.48	120.0	482
335	1.1	104.8	.3	.18	114.7	897
344	.3	110.9	2.8	.18	123.7	954
362	1.0	112.0	.4	.06	128.0	954
370	2.2	95.7	1.8	.37	112.4	835
378	2.2	117.8	0	.20	134.6	1,329
390	1.7	118.5	1.5	.40	135.0	688
391	1.1	111.1	.8	.39	127.5	1,299
404	.5	110.6	.5	.49	120.9	1,579
418	3.4	102.1	1.8	.49	113.4	1,103
422	2.4	98.9	.3	.37	113.9	1,225
438	2.2	107.9	1.8	.04	116.8	919
440	3.0	105.5	.4	.22	113.5	775
464	1.6	107.6	3.2	.26	117.5	992
466	1.1	107.9	2.1	.64	116.4	1,381
488	1.9	116.5	0	.05	124.0	1,399
492	2.4	109.6	2.2	.48	117.1	1,031
519	1.3	127.7	.4	.12	131.1	1,213
522	1.5	113.0	0	.31	115.6	965
536	2.0	132.7	1.4	.09	136.6	756
559	1.7	124.0	.3	.08	129.6	1,231
570	1.0	123.1	1.3	.16	125.9	1,611
578	.7	104.7	.1	.84	107.7	1,429
590	2.1	117.3	3.2	.21	126.3	892
592	.9	127.9	.4	.16	136.9	433

TABLE II.- RESULTS OF MEASURED LANDING-CONTACT PARAMETERS FOR 331 LANDINGS OF FIVE TYPES OF TURBOJET TRANSPORTS - Concluded

(e) Turbojet E (34 landings)

Landing identification number	Vertical velocity, ft/sec	Horizontal velocity, knots	Rolling velocity, deg/sec	Bank angle, deg	Airspeed, knots	Touchdown distance, ft
124	1.6	134.7	1.7	0.08	141.2	802
133	1.5	119.4	0	.36	128.8	1,308
146	.7	118.9	.4	.56	126.4	1,204
190	2.7	130.2	0	.06	144.0	289
194	2.9	116.8	5.3	1.48	129.8	1,036
196	1.7	126.5	0	.08	140.6	1,210
210	1.5	122.0	3.4	3.64	134.3	827
212	2.2	122.3	3.4	1.50	133.8	811
250	2.0	125.0	.1	1.31	133.4	1,135
255	1.4	114.7	4.5	.01	120.3	1,467
262	2.0	121.8	5.2	.06	127.4	870
276	.9	120.7	5.3	.18	125.9	1,367
288	1.8	115.3	1.7	.26	120.5	665
309	4.6	128.9	1.0	2.08	136.8	65
312	.5	111.7	2.2	.29	123.5	930
323	2.5	113.7	7.3	.34	126.5	627
332	1.5	118.1	3.0	1.04	127.9	995
333	.2	109.2	.9	.06	119.0	1,266
351	1.4	107.6	6.1	.09	124.3	1,410
366	2.6	106.0	.6	1.04	121.7	1,549
384	2.6	111.9	7.0	1.45	128.3	1,044
389	1.0	113.0	6.0	.57	129.4	1,302
392	3.9	109.0	4.3	.65	125.4	1,106
406	2.1	110.9	7.0	.32	121.2	722
423	.9	96.8	3.2	.37	111.8	650
442	2.9	113.5	.1	1.08	121.5	1,295
452	1.3	111.6	.2	1.35	120.6	1,805
468	1.3	115.2	7.7	.18	124.6	1,385
469	1.5	117.0	.9	1.59	125.4	1,006
483	.9	110.8	2.7	.11	118.3	1,253
524	1.9	125.7	1.4	1.50	128.3	1,611
529	1.0	127.7	6.4	.12	130.3	930
539	.5	117.4	5.7	.17	121.2	1,363
551	2.1	128.8	.9	1.78	134.5	1,081

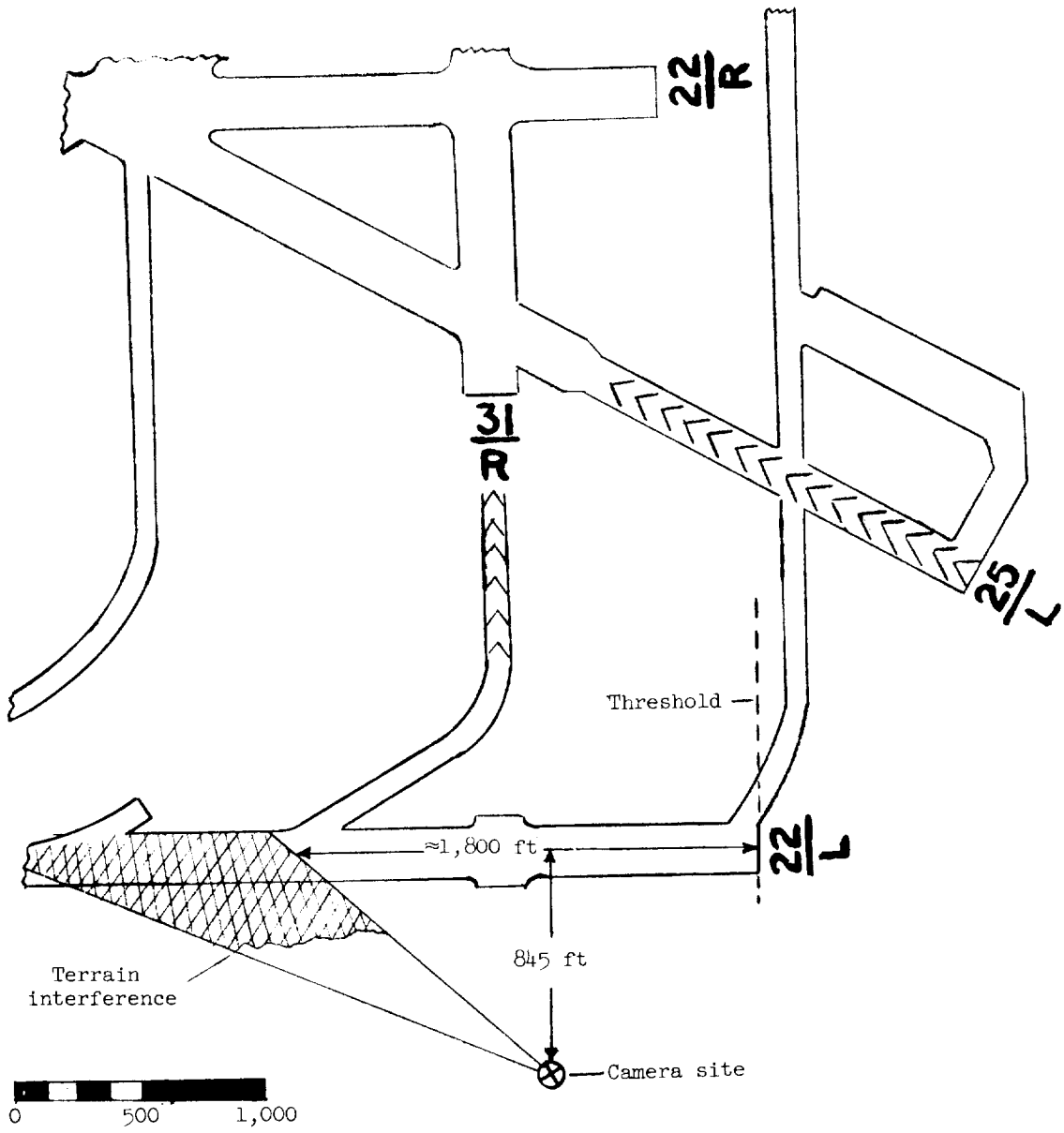


Figure 1.- Sketch showing camera location, threshold, and approximate area blocked by terrain.

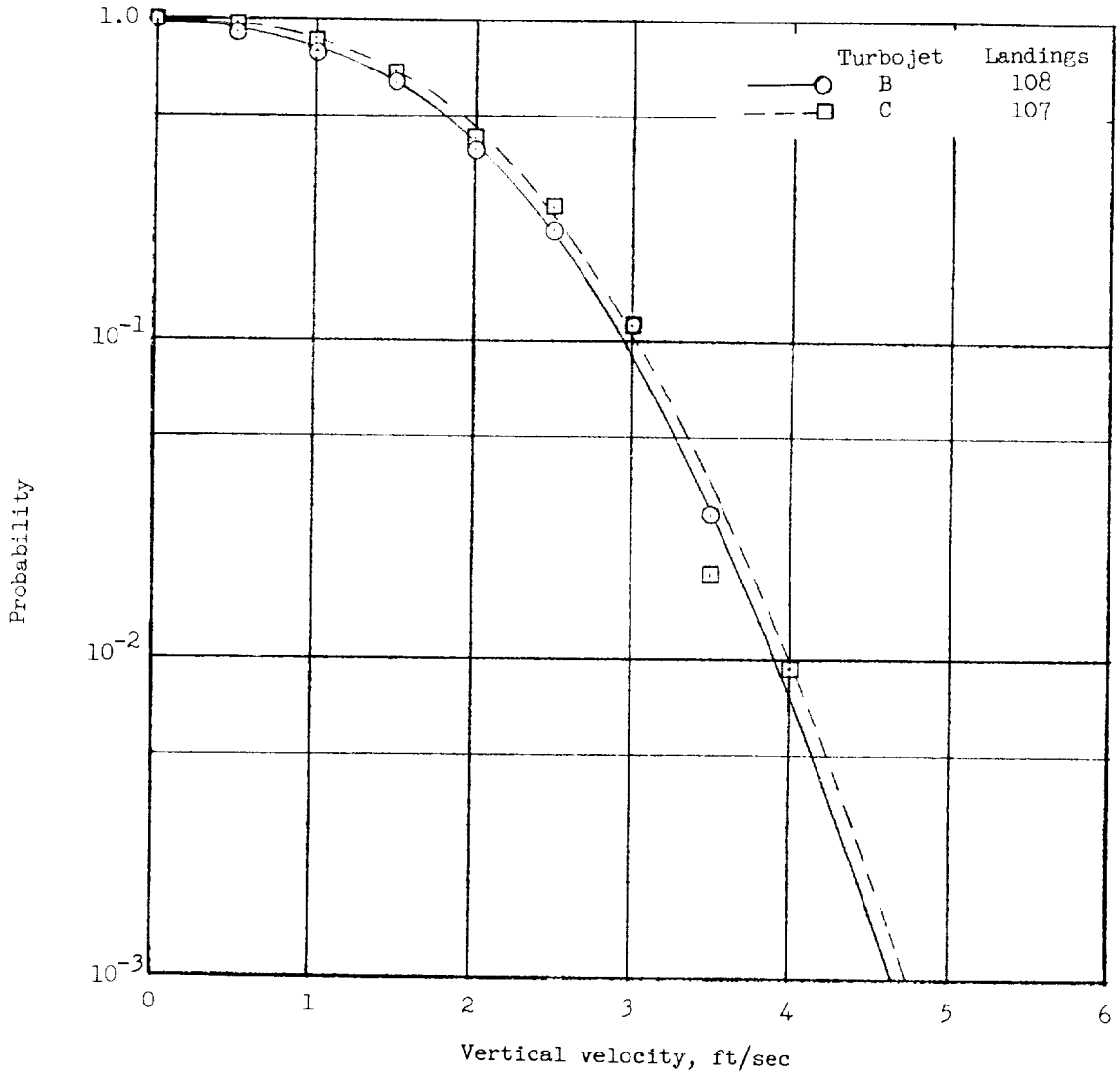


Figure 2.- Probability distributions of vertical velocity at touchdown for turbojets B and C.

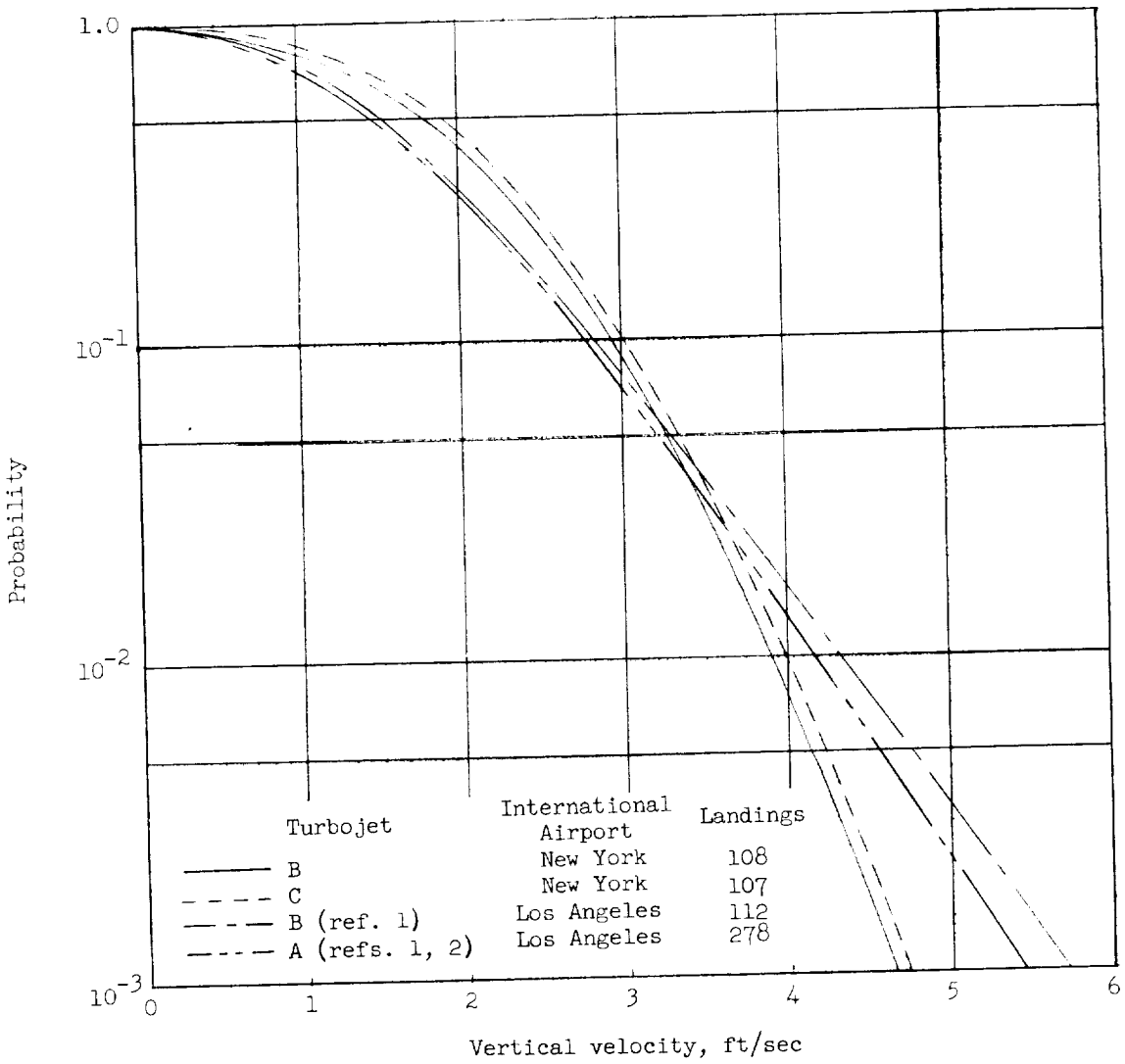


Figure 3.- Comparison of probability distributions of vertical velocity at touchdown for turbojets B and C in this investigation and turbojets A and B from references 1 and 2.

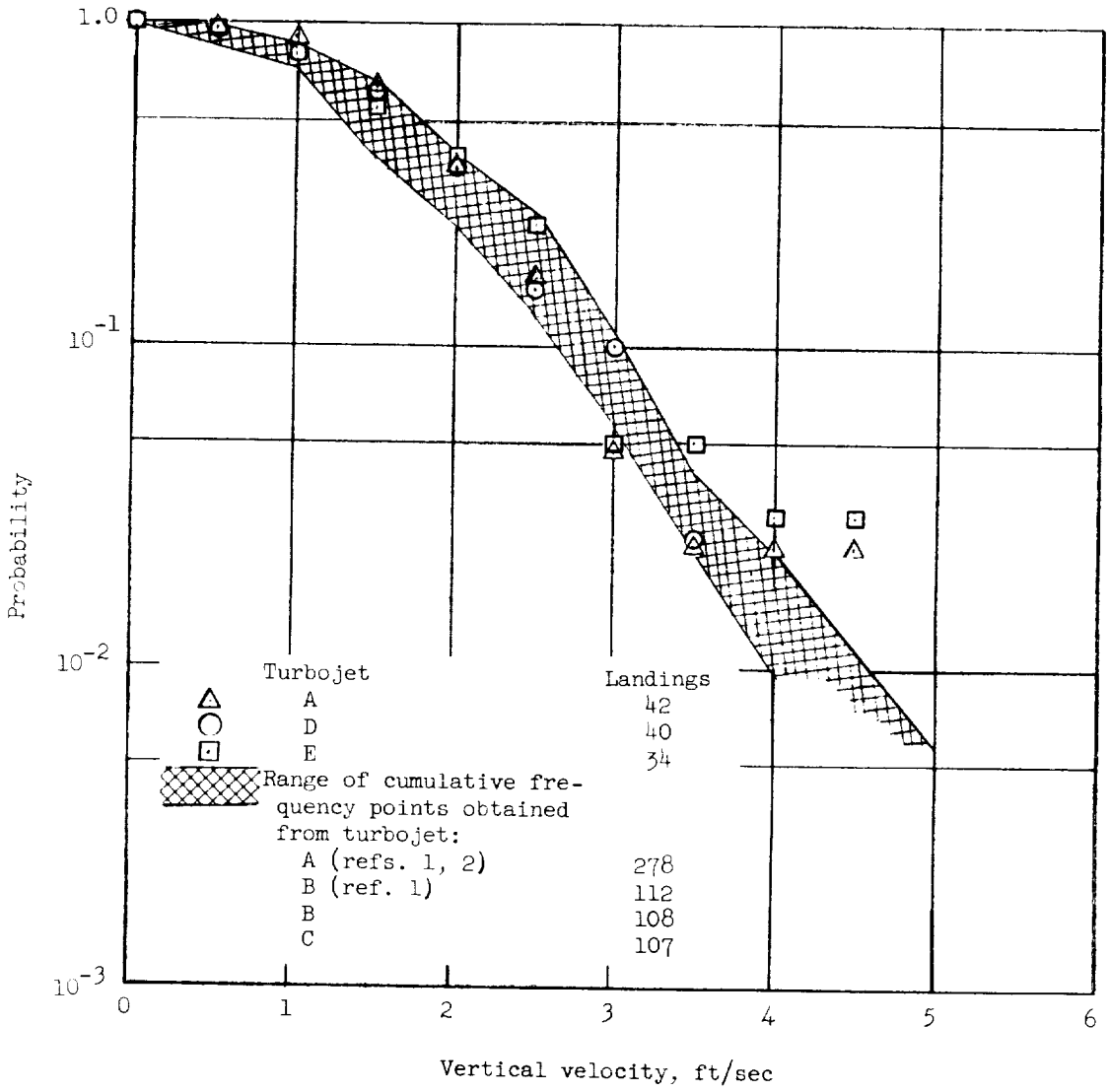


Figure 4.- Comparison of cumulative frequency points of vertical velocity at touchdown for turbojets A, D, and E with the range of cumulative frequency points (in which 100 or more landings of each type were measured) for turbojets A and B of references 1 and 2 and for turbojets B and C of this investigation.

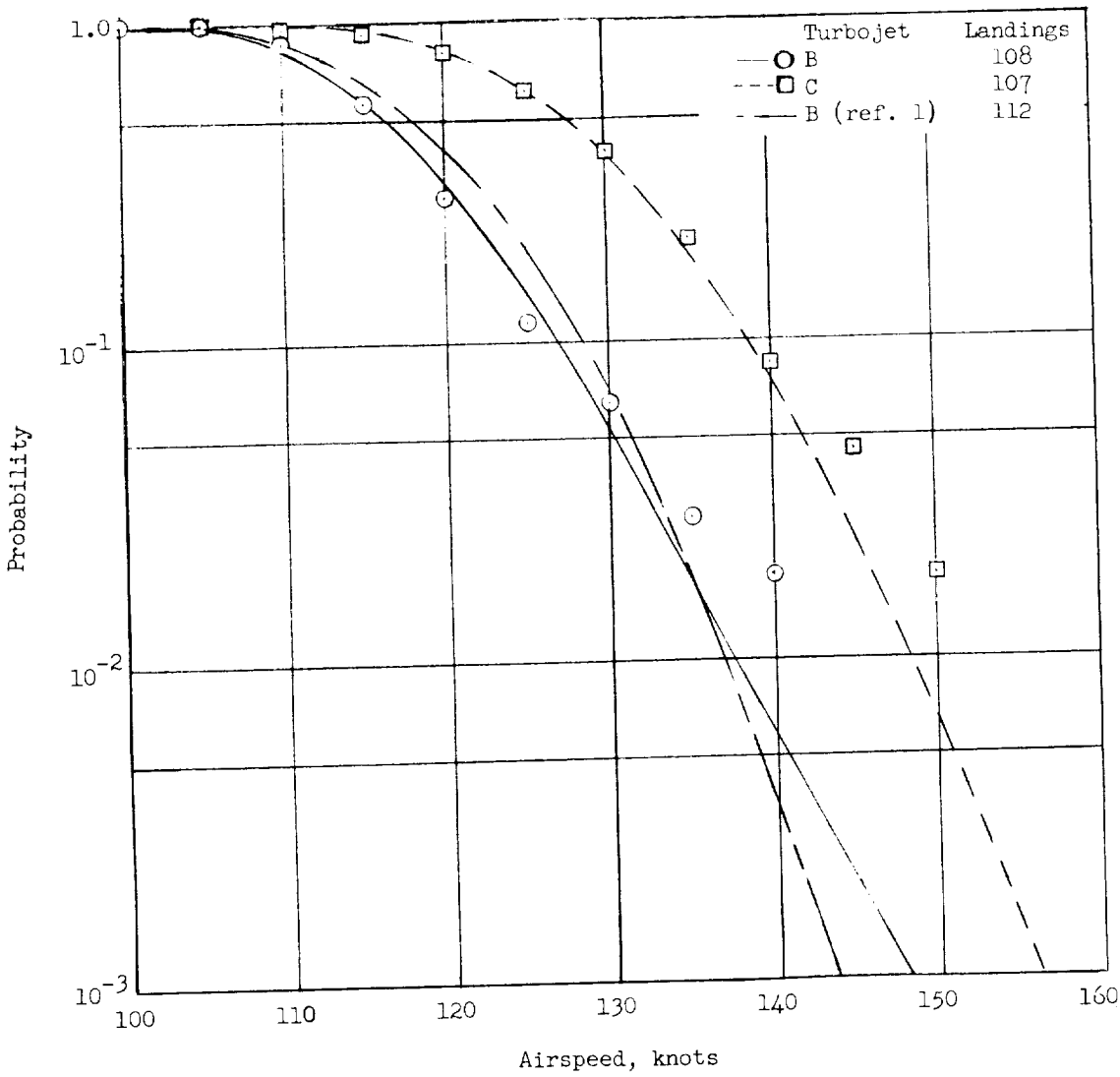
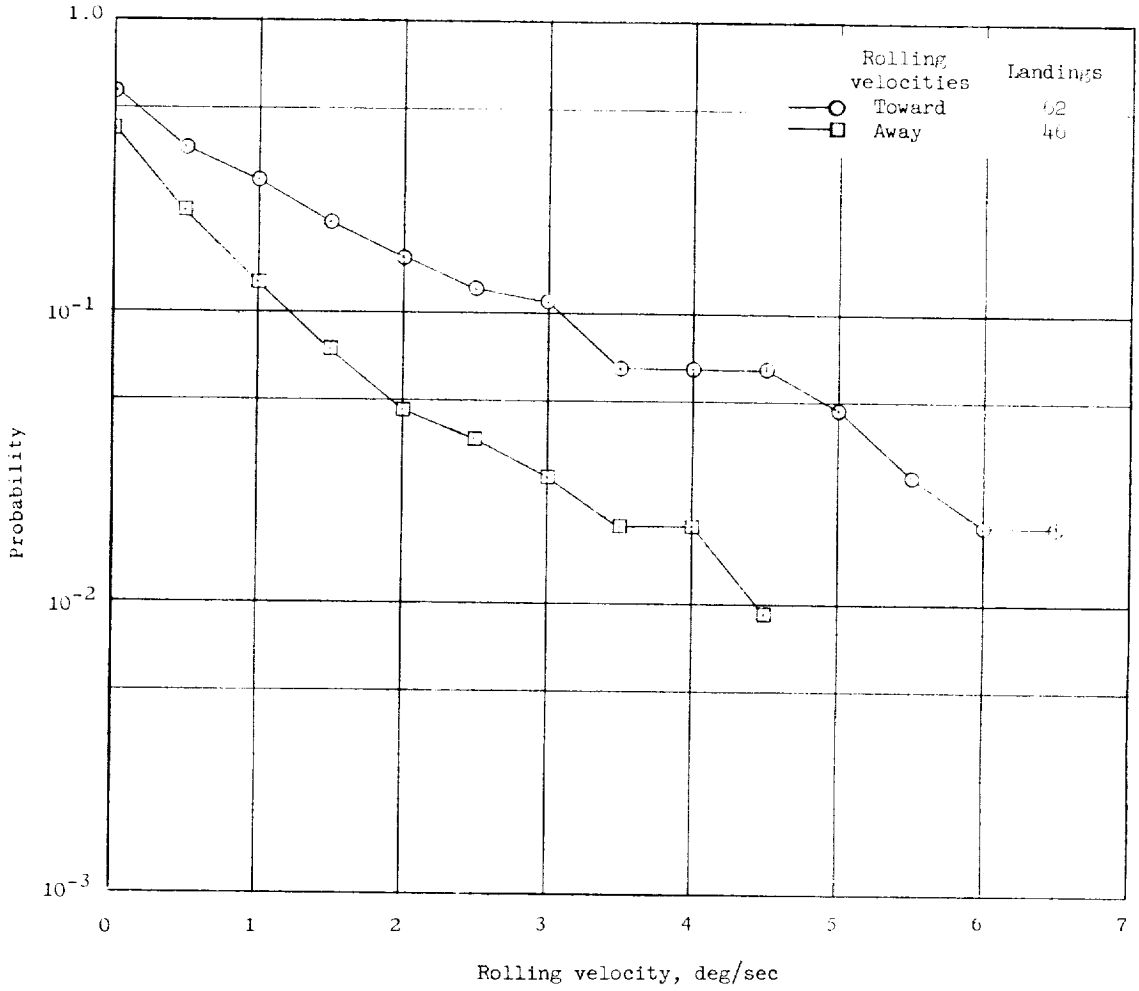
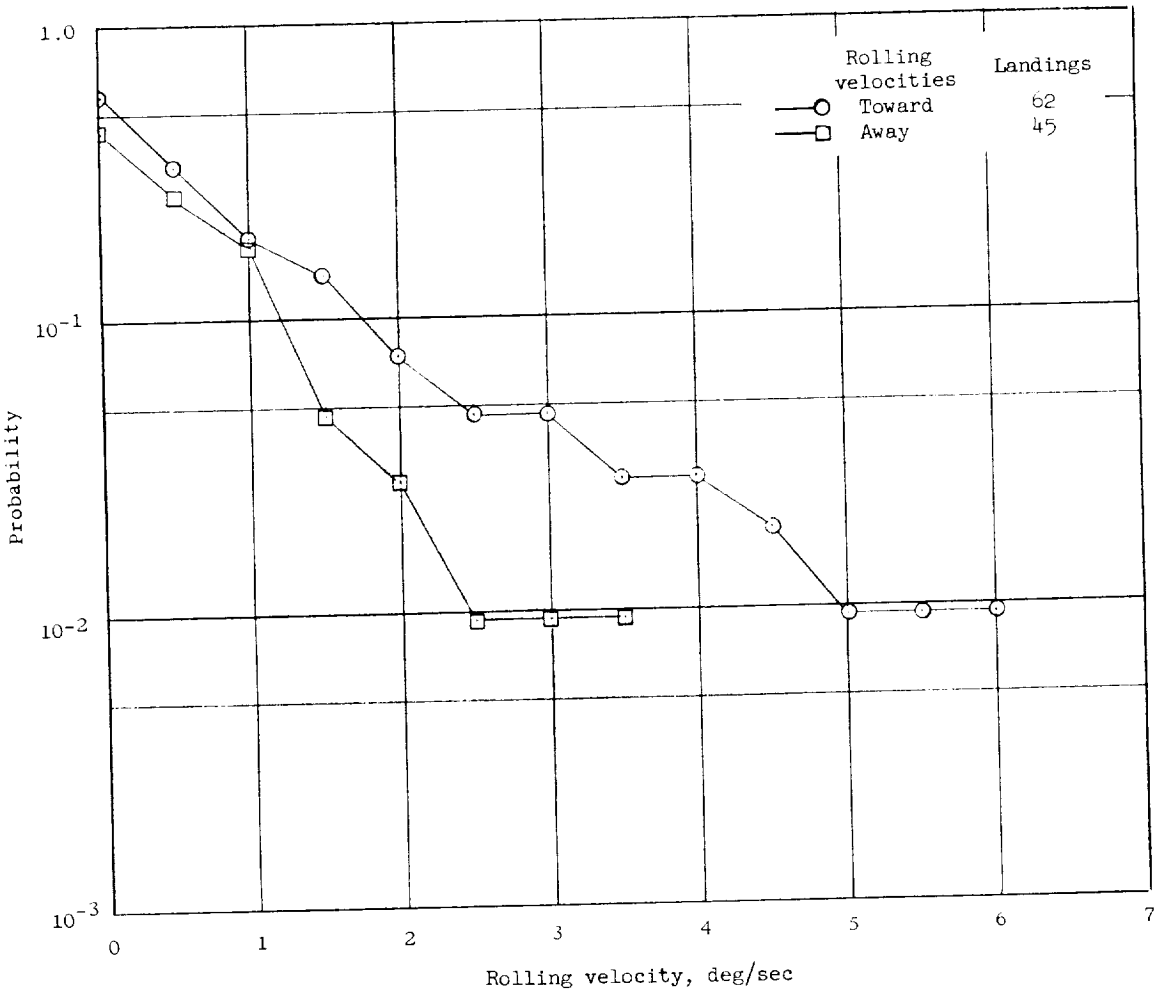


Figure 5.- Comparison of distributions of touchdown airspeed for turbojets B and C from this investigation and turbojet B from reference 1.



(a) Turbojet B.

Figure 6.- Probability distributions of rolling velocities at touchdown for rolling both toward the first wheel to touch and away from the first wheel to touch.



(b) Turbojet C.

Figure 6.- Concluded.

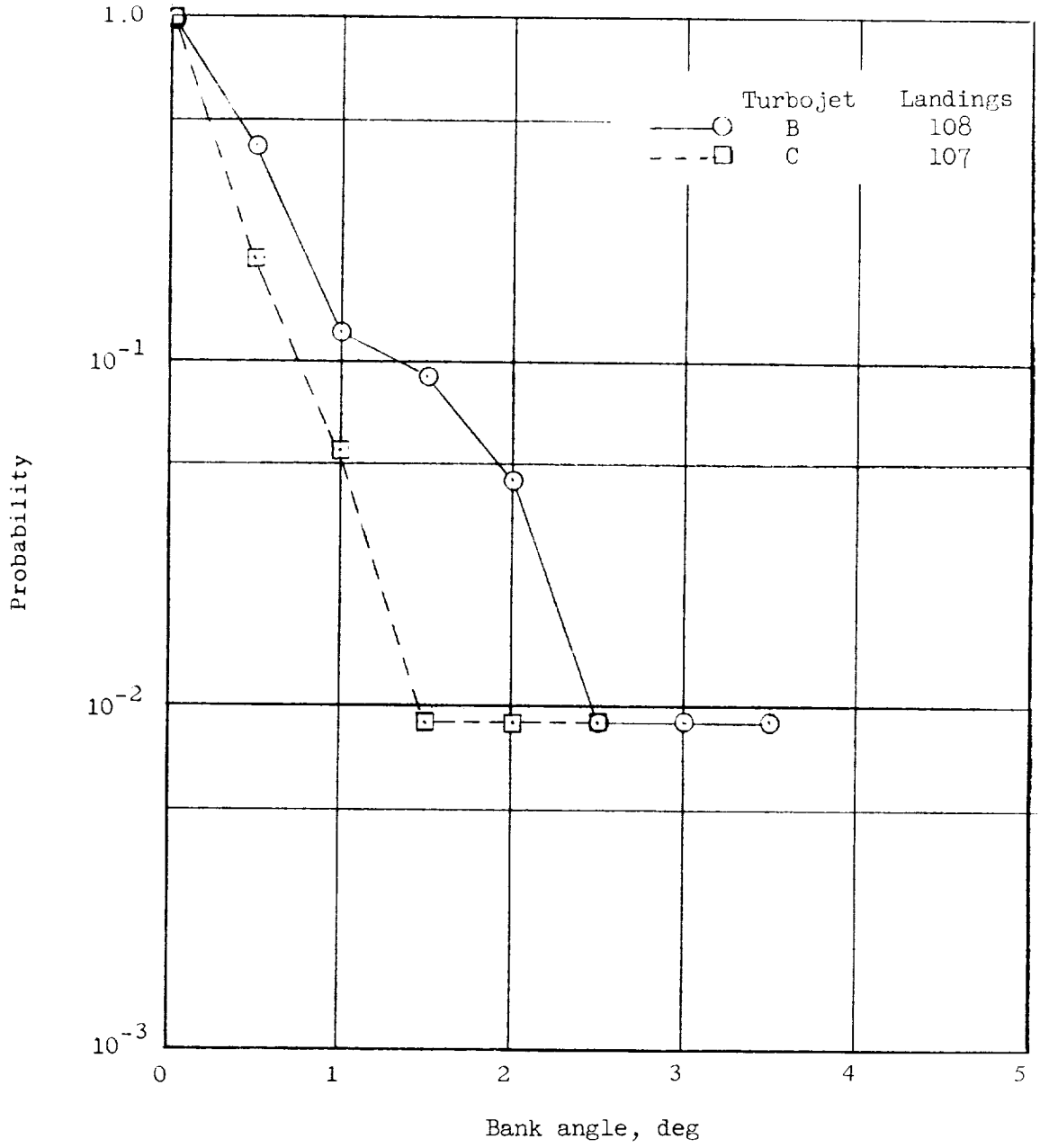


Figure 7.- Cumulative-frequency distributions of bank angle at touchdown for turbojets B and C.